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BIOLOGICAL STUDIES IN MASSACHUSETTS, No. 1.

By G. C. Whipple.

Within recent years the subject of sanitary biology has become one of great importance. The marvelous discoveries and practical applications of bacteriology have been of benefit to surgeon and sanitarian, and the people of the world to-day are better able to fight disease than ever before. Scientists all over the world are assisting in the work of establishing proper relations between man and his microscopic neighbors. Admitting, as we must, that the most important and far-reaching discoveries have eminated from the continent of Europe, we ought not to overlook the work that is being done on this side of the Atlantic, which is by no means insignificant or second-rate. To prove this it is not necessary to mention the names of men who have already acquired a reputation beyond our own borders, their work is evident in our improving water supplies, our better methods in all departments of sanitation, and the increasing popular appreciation of cleanliness.

There is one branch of sanitary biology that has been carried on more extensively in Massachusetts than anywhere else,—namely, the microscopical examination[1] of drinking water; and it is, therefore, perhaps not undeserving of the brief description here to be given.

It is unnecessary to relate the early history of the subject in this state, for, although the work of Nichols, Farlow, and others, was most interesting and valuable, it was not until the State Board of Health began its investigations in 1887 that much attention was given to the quantitative determination of the microscopical organisms. The method of examination first used was the "cloth method" of G. H. Parker. Two hundred cubic centimeters of the water was poured through a funnel over the neck of which a piece of fine cloth was firmly tied, and the organisms caught by the cloth were subsequently transferred to a small quantity of water, and placed under the microscope for identification and enumeration. In June, 1889, the "cloth method" was superseded by the "sand method" devised by A. L. Kean, and improved by Prof. Sedgwick. The water was filtered through sand instead of cloth, after which the sand with its collected organisms was washed into a deep cell and placed on the stage of the microscope. To assist in the enumeration the bottom of the cell was ruled in squares. This method was used until November, 1890, when the Sedgwick-Rafter method, hereafter described, was adopted. This method, with but slight modifications, has been used to the present time. In the course of the whole series of investigations by the State Board of Health it is estimated that upwards of 16,000 samples of water have been submitted to microscopical examination—2,000 by the cloth method, 2,000 by the sand method, and 12,000 by the Sedgwick-Rafter method. The samples cover all parts of the state, and include almost all possible sources of water supply—lakes, ponds, artificial reservoirs, brooks, rivers, springs, wells, filter galleries, etc.

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[1] The microscopical examination deals only with the comparatively large forms of micro-organisms, such as the algæ, infusoria, etc., and is not concerned with the bacteria, the study of which forms an entirely distinct branch of sanitary biology.

Next in importance to the work of the State Board of Health, and in some respects surpassing it, is the biological work of the Boston Water Supply Department. These investigations have involved the examination of more than 20,000 samples of water, collected chiefly from the various portions of the city supply. The Sedgwick-Rafter method has been used from the start, though from time to time several improvements have been introduced.

In the summer of 1893 the Public Water Board of the City of Lynn fitted up a biological laboratory in the basement of the city hall for the weekly microscopical and bacteriological examination of the water supply. The bacteriological work was not continued long, but the microscopical examinations are still being made. The total number of examinations by the Sedgwick-Rafter method now exceeds 2,000.

The grand total of the number of microscopical examinations made in these three laboratories added to a large number made by F. F. Forbes in his studies of the Brookline water, and by others interested in the subject, is not far from 40,000.

As the biological laboratory of the Boston Water Works is typical of the methods and nature of the work under discussion, a description of it will occupy the remaining portion of this paper. It was established in the fall of 1889 by Mr. Desmond Fitz Gerald, C. E., Supt. of the Western Division of the Water Works, and since then the work has been carried on under his general direction. Prof. James I. Peck had charge of the laboratory during the first few months of its existence; but since January 1, 1890, it has been in charge of the writer. The working force consists of one biologist, two (sometimes three) assistant biologists, and a number of attendants at the various reservoirs who devote a portion of their time to the collecting of samples, the observation of temperature, etc. The laboratory building is situated upon the shore of the beautiful Chestnut Hill Reservoir. (Plate XIII.) It is near the high service pumping station,from which it receives steam heat and electric light. A gas machine supplies it with gas.

The object of the laboratory work is to ascertain and keep record of the condition of the water in all parts of the supply at all times. Reports are made weekly to the Superintendent and Water Commissioner. These enable the supply to be managed in the best possible manner so far as the quality of the water is concerned, and they have more than once prevented water of inferior quality from being sent into the city.

The work of the laboratory may be considered under the following heads: 1. Environmental and Physical; 2. Microscopical; 3. Bacteriological; 4. Photomicrographical; 5. Experimental.

1. *Environmental and Physical.*—Samples of water for examination are collected weekly from all parts of the supply, namely, from Lake Cochituate, the Sudbury Storage Reservoirs and their inflowing streams, the aqueducts, distributing reservoirs and service pipes, and sent by express to the laboratory. Glass-stoppered, one-litre bottles are used, thoroughly packed in felt-lined boxes. In all the reservoirs samples are collected at the surface, mid-depth, and bottom. The following apparatus (Plate XIV.) has been found the most convenient for securing samples from beneath the surface. The frame for holding

the bottle consists of a brass wire (A) attached to a weight (B) from which strips of brass extend upwards terminating in clips (C). These brass strips have considerable spring, and serve to hold the bottle in place. The frame is supported by the spring (F) attached to the sinking rope (E). A flexible cord (G) extends from the top of the spring (E) to the stopper (H) of the bottle. The length of this cord and the length and stiffness of the spring are so adjusted that when the apparatus is suspended in the water the flexible cord will be a little slack. In this condition it is lowered to the required depth. A sudded jerk given to the sinking rope stretches the spring, produces tension on the flexible cord, and pulls out the stopper. A slack safety cord (not shown in the figure) extends from E to J to prevent too great a stretching of the spring and to guard against loss of apparatus in case the spring should break. For great depths, where the pressure is too great to allow of the stopper being removed, a smaller aperture is used.

The temperature of each sample is recorded at the time of collection, and additional series of observations upon the temperature of the water at various depth are carried on, using for this purpose the newly invented Thermophone. These observations give useful information regarding the circulation of the water. When the samples reach the laboratory, record is made of the color (using the platinum-cobalt standard in a colorimeter of special design), transparency, amount of sediment, taste, and odor.

Environmental studies are carried on by personal inspection of the watershed, and the collection of numerous extra samples from the small brooks and feeders. These inspection trips are made whenever anything abnormal appears in the condition of the water.

2. *Microscopical.*—The microscopical work is the most important part of the laboratory routine. It consists chiefly in the quantitative determination of the various micro-organisms (except the bacteria) in each sample of water by the Sedgwick-Rafter method. At the present time this is carried on as follows: 500 c.c. of the water to be examined is filtered through a thin layer of quartz sand supported at the bottom of a cylin-

drical glass funnel upon a perforated rubber stopper, covered with a disc of bolting cloth, the filtration sometimes being hastened by the use of the aspirator. The sand with whatever organisms have collected upon it is then washed into a test tube with 5 or 10 c.c. of distilled water, thus concentrating the organisms. This tube is shaken, and the water decanted to a second tube, the sand being left behind. 1 c.c. of this fluid containing the concentrated organisms is next placed in a cell, 50 x 20 mm. and 1 mm. deep, covered with a thick cover glass and placed under the microscope. A ruled square in the micrometer ocular covers one square millimeter on the stage, *i. e.*, one-thousandth of the area of the cell. The organisms seen within this square are then counted, and the cell is moved so that other portions come into view. Having counted a definite number of these squares the determination of the number of organisms in the original sample is a matter of calculation. On account of the great variety in size which the different organisms present it has been found expedient to adopt a standard unit of size (400 square microns) in terms of which all organisms are recorded. The organisms are classified according to the following convenient grouping: 1. Diatomacæ; 2. Chlorophyceæ; 3. Cyanophyceæ; 4. Fungi; 5. Rhizopoda; 6. Infusoria; 7. Rotifera; 8. Crustacea; 9. Miscellaneous.

Occasionally microscopical examinations are made in the field, in order to study the sample while fresh and before the organisms have begun to break up. For this purpose a convenient portable outfit is provided. Another feature of the microscopical work consists of the examination of material from the shores and bottoms of the reservoirs, the organisms growing in the swamps, along the streams, and upon the walls of the aqueducts and distribution pipes.

3. *Bacteriological.*—The bacteriological work is chiefly the weekly determination of the number of bacteria in the water of the aqueducts, distribution reservoirs and service pipes by means of the ordinary methods of culture. More or less study is given to the various species observed, and a careful watch is kept for the presence of *Coli communis,* whose presence to a certain extent is considered an index of pollution. At some-

what longer intervals samples for bacteriological examination are collected from the brooks in the more thickly settled portions of the watershed and from the various filter beds. Samples from beneath the surface of the reservoirs are collected in sterilized vacuum tubes, lowered to position in heavy lead tubes; the seal is broken by an arrangement of spring and flexible cord in a manner similar to that described above. On account of the uncertainty which surrounds the methods of bacteriology at the present day comparatively little of the bacteriological work has been published.

4. *Photomicrographical.*—For some time after the establishment of the laboratory much attention was given to the subject of photography, and excellent photomicrographs of most of the important organisms have been secured. Of late the time required for this work has been given over to the more important bacteriological investigations.

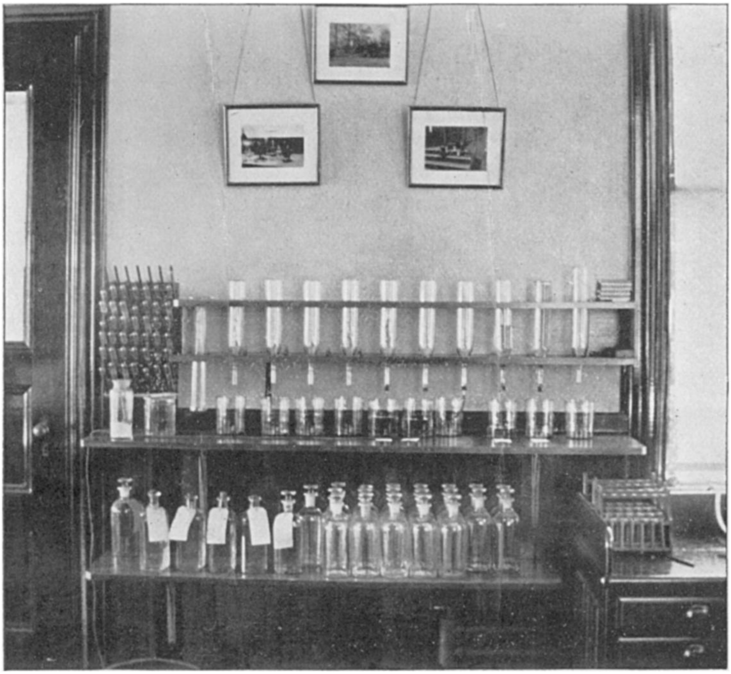
5. *Experimental.*—In addition to the routine work many experiments of a practical and scientific nature have been carried on. Of the subjects investigated the following may be given as illustrations: The cause of the seasonal distribution of the various classes of organisms. The effect of temperature, light and air upon the growth of diatoms. The cause and extent of the taste produced in water by organisms. The effect of swamps upon the quality of a water supply. A study of "stagnation phenomena" in a deep pond. The bleaching action of sunlight. The efficiency of sand and mechanical filtration in the purification of water.

Comparatively little *chemical* work is done in the laboratory, as this branch of the subject is deemed sufficiently treated in the monthly examinations of the State Board of Health.

Taken together, all the biological work of the character described that has been done in Massachusetts during the past ten years is of great value from a purely scientific as well as from a sanitary standpoint; and the increasing importance of the subject and the growing interest in limnological studies in other countries make it desirable that this work should be better known. It is the intention to bring together in this series of articles an outline of the work done, and some of the most important of the results obtained, treating the subject not so much from a sanitary as from a biological point of view.

PLATE XIII.

Biological Laboratory. Boston Water Works.



Battery of Filters. Sedgwick-Rafter Method.

PLATE XIV.

APPARATUS FOR COLLECTING SAMPLES OF WATER.

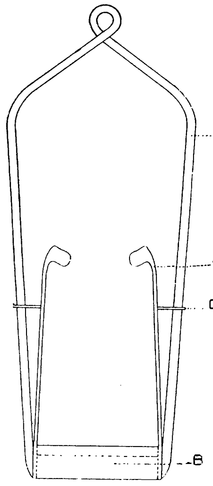


FIG. 1.

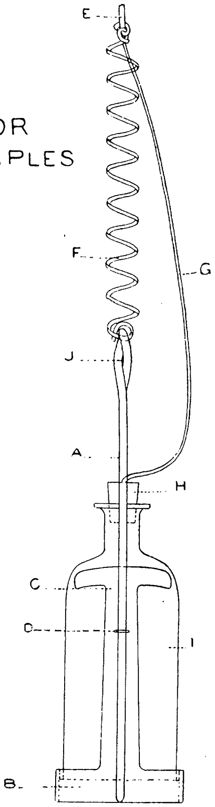


FIG. 2